MT. ETNA VOLCANIC AEROSOL AND ASH RETRIEVALS USING MERIS AND AATSR DATA

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ABSTRACT

Envisat MERIS and AATSR data have been acquired in the framework of the Eurorisk-Preview project. The project addresses European civil protections and proposes to develop, at the European scale, new information services to support the risk management. In Italy one of the most important natural risks is due to the presence of volcanoes. Mt. Etna in Sicily, displays persistent activity, periodically interrupted by eruptions, which emit volcanic aerosol and ash to different altitudes in troposphere affecting the central Mediterranean area. In order to test the use of MERIS and AATSR data to derive emitted particles parameters as optical depth, effective radius and the ash mass of particles, the already developed remote sensing techniques has been adapted. MERIS and AATSR data acquired during the Mt. Etna 2002-2003 volcanic eruption has been chosen.
The use of VIS and TIR bands of the two sensor demonstrates the potential to derive useful information on plume particles and to monitor the volcanic plume during eruption if frequent and high resolution data is available in near real time.

1. INTRODUCTION

The European Union EURORISK-PREVIEW project for the earthquakes and volcanoes platform is addressed to the European Civil Protections and proposes to develop, at the European scale, new information services to support the management of risks, of significant added value, making the best use of the most advanced research and technology outcomes and validated under pre-operational conditions. In order to study the volcanic emissions in atmosphere Mt. Etna, located in the eastern part of Sicily (Italy), has been chosen as test site.

2. THE 2002-2003 MT. ETNA ERUPTION

Mt. Etna is a large strato-volcano producing alkaline and basaltic lava during summit and flank eruptions. Etna is one of the world’s most actively degassing volcanoes; an important feature of its activity is the continuous and abundant degassing from the summit craters. This degassing process produces a plume rich in gases, ash and aerosols. During the 2002-2003 eruption a large amount of gas and particulates, such as ash and aerosols, have been emitted in troposphere producing high risk for aviation safety in the central Mediterranean area combined with risk for population health and for building security [1].

3. VOLCANIC AEROSOL AND ASH RETRIEVAL ALGHORITHMS

Three different algorithms have been applied to the Envisat MERIS and AATSR data, simultaneously acquired over Mt. Etna on 28 October 2002. The three algorithms differs in retrieval techniques, instrument and spectral range but applied the same volcanic ash optical properties. The ash optical properties have been computed using Mie code (http://www.atm.ox.ac.uk/code/mie/index.html) considering the volcanic ash refractive index tabulated by Volz (Volz_1973) and a log-normal size distribution.

3.1 MERIS-VIS

The radiative transfer inversion algorithm [2] has been applied to MERIS data. The algorithm uses the visible channels, since scattering effects occurs in the short wavelength range of the solar spectrum. The algorithm retrieves explosive plume particles optical characteristics as a spatial distribution of optical thickness and Amstrong parameters (Figure 1). The AOT map (see Plate a in Figure 1a) shows that two volcanic plumes are well identified, especially the lower one emitted from North fracture. From the spectral behaviour of AOT, Angstrom parameter Alpha has been derived (see Plate b in Figure 1b), showing the presence of bigger particles in the main eruptive plume.

3.2 AATSR-ORAC

The Oxford-RAL retrieval algorithm of Aerosol and Cloud properties (ORAC) [3-4] algorithm, developed at Oxford University and Rutherford Appleton Laboratory, has been applied to AATSR visible and near infrared channels.
The algorithm uses the Levenburg-Marquardt method to fit the simulated radiance to the measurements, minimising a cost function based on optimal estimation (OE) techniques [4].
The ORAC scheme has been used and validated in several projects including NERC GRAPE and ESA Globaerosol. The radiative transfer model used for the vis/nir channels takes into account atmospheric scattering and absorption as obtained by DISORT

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(DIScrete Ordinate Radiative Transfer) radiative transfer code. The algorithm is extended to include the optical properties of a volcanic aerosol model. The algorithm retrieves aerosol optical depth at 0.55 µm, effective radius and surface albedo (Figure 2).

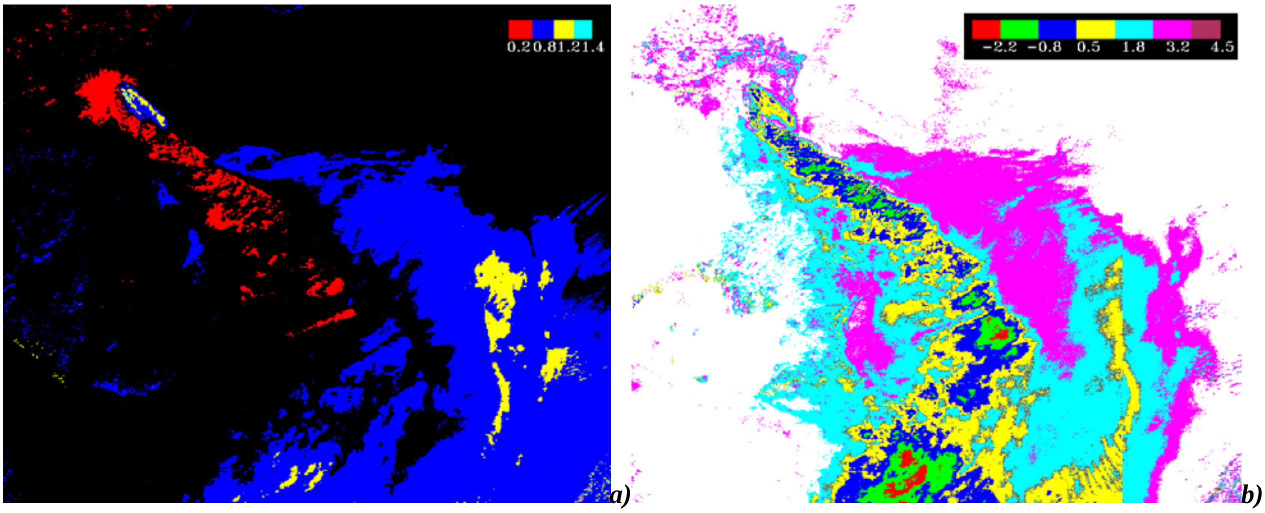


Figure 1. (a) MERIS derived AOT map; (b) MERIS derived Angstrom parameter Alpha.

3.3 AATSR-TIR

Using multispectral TIR bands, around 11 and 12 micron, the possibility to detect the ash component during eruptive episodes has been demonstrated using the BTD method [5,6]. This method has been applied to AATSR data choosing the same eruption episodes recorded by MERIS and the same AATSR data as the visible retrieval; to take into account the atmospheric water vapour absorption in the 11-12 µm spectral range, a water vapour correction procedure has also been also considered [7]. After calculating the optical properties of the volcanic ash a radiative transfer model has been used to simulated the signal measured by AATSR. Fitting the model simulations to the data provides estimates of the optical thickness of the eruptive plume, radius of the ash particles and the ash loading (Figure 3).

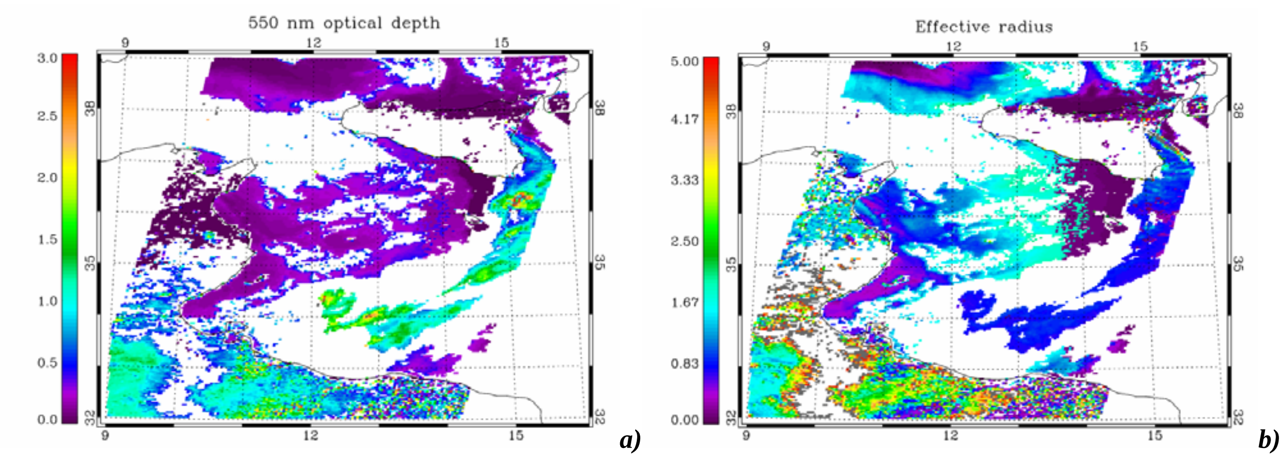
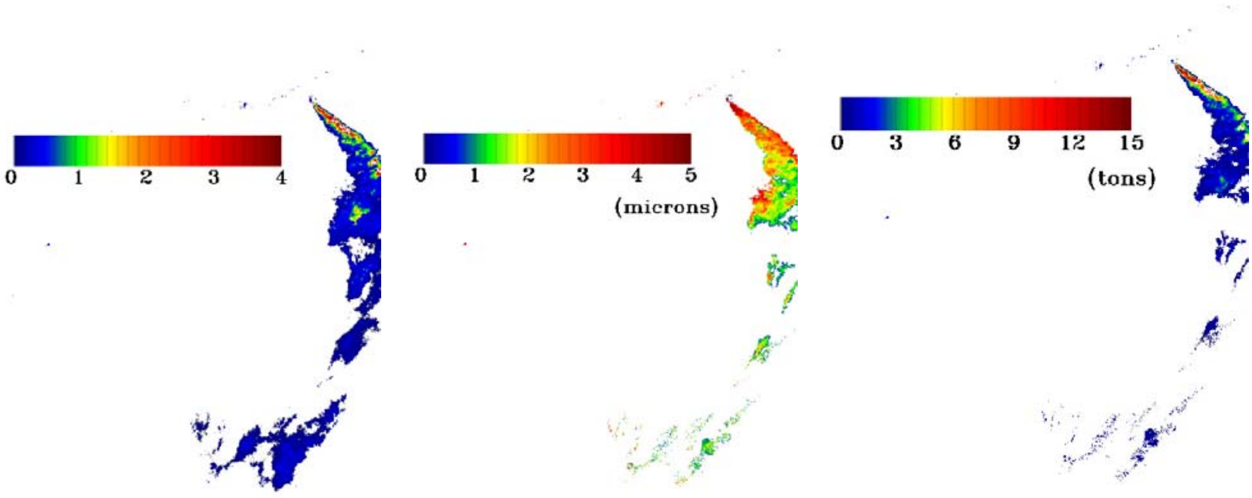


Figure 2. (a)AATSR derived AOT map; (b) AATSR derived particle effective radius.



a) *b)* *c)*

Figure 3. (a)AATSR derived AOT map; (b) AATSR derived particle effective radius; (c) AATSR derived ash mass.

5. CONCLUSIONS

Results have been obtained from three different methods of retrievals which have been applied to simultaneously acquired AASTR and MERIS data over Mt. Etna during the 2002-03 eruption using same volcanic particles optical properties.

The AOT and Angstrom parameter resulting from MERIS identify two volcanic plumes: the main eruptive one composed of bigger particles (> 1 µm) and a second composed of smaller particles.

The ORAC forward model retrieves aerosol optical depth at 0.55 µm and effective radius for the eruptive plume.

The BTD calculates the ash particle size and the total ash mass resulting in 11440 t.

The comparison shows that the ash plume is well identify by the three methods. Each one add a parameter that characterize the plume. The methods that use Visible channels are most sensitive to the finer particles while BTD methods using TIR is well suited for ash component retrieval.

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REFERENCES

[1] Andronico A., Branca S.,· Calvari S.,·Burton M.,·Caltabiano T.,·Corsaro R. A.., · Del Carlo P., ·Garfì G., Lodato L.· Miraglia L., Murè F., Neri M.,· Pecora E., Pompilio M., Salerno G.,· Spampinato L., 2005. A multi-disciplinary study of the 2002–03 Etna eruption: insights into a complex plumbing system. Bull Volcanol (2005) 67:314–330. DOI 10.1007/s00445-004-0372-8

[2] Spinetti C., M.F. Buongiorno, V. Lombardo, and L. Merucci, 2003. Aerosol Optical Thickness of Mt. Etna Volcanic Plume Retrieved by Means of the Airborne Multispectral Imaging Spectrometer MIVIS. *Annals of Geophysics* 46 N.2

[3] Thomas G.E., C.A. Poulsen, A.M. Sayer , S.H. Marsh, S. M. Dean, E. Carboni, R. Siddans, R.G. Grainger, and B.N. Lawrence, 'The GRAPE aerosol retrieval algorithm', submitted to ACP.

[4] Thomas G. E., Dean S. M., Carboni E, Grainger R.G.,Poulsen C.A., Siddans R. and Kerridge B. J. (2005) "ATSR-2/AATSR algorithm theoretical base document. ESA Globaerosol ATBD.

[5] Prata, A. J., 1989a. Observations of volcanic ash clouds in the 10–12 µm window using AVHRR/2 13 data. Int. J. Rem. Sens. 10 (4-5): 751-761.

[6] Wen, S., Rose, W. I., 1994. "Retrieval of sizes and total masses of particles in volcanic clouds using AVHRR bands 4 and 5. J. Geophys. Res. 99 (D3): 5421-5431.

[7] Corradini, S., Spinetti, C., Carboni, E., Tirelli, C., Buongiorno, M. F., Pugnaghi, S., and Gangale, G., 2007. Mt. Etna tropospheric ash retrieval and sensitivity analysis using Moderate Resolution Imaging Spectroradiometer measurements. In Review to JARS.